Contents

Michael James Keller

```
clc
clear
% ¯\_(?)_/¯
```

Varible setup

```
% shafts
diameter_motor_shaft = 0.75; %mm
diameter_intermediate_shaft = 0.75; %19.05 mm to 0.75 inches
diameter_drive_shaft = 1.25; %31.75 mm to 1.25 inches


% Other
step = 2;
```

stepping through 14-19 design layout, page 767

```
% function
    % Load
    torque_out = 12*47.13022; %69.3Nm, convert to inch-lbs
    % Speed - RPM
    rpm_in = 360; %360 rpm to omega
```

```
    rpm_out = 90; % 90 rpm to omega
    % Reliability
    safety_factor = 1.5;
    % life
    life_hours = 24*365*5;
    life_minutes = life_hours*60;
    % K_o

% Unquantifiable risk

% Tooth System
    % Pressure Angle
        phi = 14.5; % pressure angle
    % Addendum
        % a pitch of 4 seems to give standardized numbers for diameter, 8.5
        % and 4.25
        %pitch = [2 2.25 2.5 3 4 6 8 10 12 16 20 24 32 40 48]; % Set pitch:  p = N/d, 16 is a
vailible at McMaster
        pitch = 10;
        addendum = 1./pitch;
    % Dedendum
        deddendum = 1.25./pitch;
    % Root fillet radius

% Gear Ratio
    % Gear Ratio
        % Page 692, example 13-3
        gear_ratio = rpm_out/rpm_in;
        ratio_per_step = gear_ratio^(1/step);
        fprintf("Question 1: \n")
        fprintf("Reduction per step = %.2f or 2:1\n",ratio_per_step)
    % N_p_theoretical (number of teeth on pinion)
        % Page 678, Equation 13-11
        m = 1/ratio_per_step; % gear teeth ration, per step
        k = .8; % 1 for full depth teeth, 0.8 for stub teeth
        % need to use stub teeth
        N_p_theory = ceil(((2*k)/((1+2*m)*sind(phi)^2))*(m+sqrt(m^2+(1+2*m)*sin(phi)^2)));
    % N_g_theoretical (number of teeth on gear)
        % Page 679, Equation 13-12
        N_g_max = (N_p_theory^2 * sind(phi)^2 - 4*k^2)/(4*k - 2*N_p_theory*sind(phi)^2);
        % Find required mating gear for pinion
        N_g_theory = N_p_theory * (1/ratio_per_step);

% Choseing gears
    %6867K79 for pinion 1 and 3,
    %6325K9 for gear 2 and 4
    gear1.name = '6867K79';
    gear1.pitch = 10;
    gear1.pitch_diameter = 3;
    gear1.face_width = 1;
    gear1.teeth = 30;

    gear2.name = '6325K9';
    gear2.pitch = 10;
    gear2.pitch_diameter = 6;
    gear2.face_width = 1;
    gear2.teeth = 60;
```

```
        fprintf("Number of teeth on pinion 1 = %2.0f \n",gear1.teeth)
        fprintf("Number of teeth on pinion 3 = %2.0f \n",gear1.teeth)
        fprintf("Number of teeth on gear 2 = %2.0f \n",gear2.teeth)
        fprintf("Number of teeth on gear 4 = %2.0f \n",gear2.teeth)
% Quality Number
% Diametral Pitch
    diameter_pinion = gear1.pitch_diameter; %N_p_theory ./ pitch;
    diameter_gear = gear2.pitch_diameter; %N_g_theory ./ pitch;
    % gears 1 and 3 are pinions, 2 and 4 are gears
    %
    diameter_1 = diameter_pinion;
    diameter_2 = diameter_gear;
    diameter_3 = diameter_pinion;
    diameter_4 = diameter_gear;
% Face Width
    face_width = gear1.face_width; % from Mcmaster
% Pinion Material
    s_t_steel = 25000; %psi
    s_t_brass = 10000; %psi, page 742, hardness 350
    s_c_steel = 141000; %psi, change if you harden it
    s_c_brass = 40000; %psi
% Gear Material
```

```
Question 1:
Reduction per step = 0.50 or 2:1
Number of teeth on pinion 1 = 30
Number of teeth on pinion 3 = 30
Number of teeth on gear 2 = 60
Number of teeth on gear 4 = 60
```

Solving Example

Pinion Bending

```
    F = 1;% 4*pi/pitch; % face width theoretical
```

Finding omega for each gear

```
rpm_2 = rpm_in*(N_p_theory/N_g_theory);
rpm_3 = rpm_2; % on same shaft
fprintf("Question 4: \n")
fprintf("Intermediate shaft rotational speed = %3.0f rpm \n",rpm_2)
```

```
Question 4:
Intermediate shaft rotational speed = 180 rpm
```

Finding Torque on each gear

```
torque_3 = torque_out*(rpm_out/rpm_3); %pound feet
```

```
torque_2 = torque_3*(rpm_3/rpm_2);
torque_in = torque_2*(rpm_2/rpm_in);
fprintf("Torque on intermediate shaft = %f inch-Lbs \n",torque_2)
```

```
Torque on intermediate shaft = 282.781320 inch-Lbs
```

w_t, transmitted tangental load, on each gear - page 697, 13-14

```
w_t_1 = 2*torque_in/diameter_1; %pounds
w_t_2 = 2*torque_2/diameter_2;
w_t_3 = 2*torque_3/diameter_3;
w_t_4 = 2*torque_out/diameter_4;
fprintf("Question 5: \n")
fprintf("Transmitted tangental load on drive shaft = %f Lbs \n",w_t_4)
```

```
Question 5:
Transmitted tangental load on drive shaft = 188.520880 Lbs
```

w_r, transmitted radial load, on each gear - page 701, 13-15

```
w_r_1 = w_t_1*tand(phi); %pounds
w_r_2 = w_t_2*tand(phi);
w_r_3 = w_t_3*tand(phi);
w_r_4 = w_t_4*tand(phi);
% Use this for bending in shafts
fprintf("Transmitted radial load on drive shaft = %f Lbs \n",w_r_4)
% if the actual radial load is less than what we used to calculate shaft
% diameter, then we should be good to use a previously designed shaft
% diameter
fprintf("The forces are just barely greater than what was used for the \ncalculations to desi
gn the original shaft but the calculations should still be reran.\nPlugging in the numbers a
shaft of 1.25 inches should still work.\n")
```

```
Transmitted radial load on drive shaft = 48.754815 Lbs
The forces are just barely greater than what was used for the
calculations to design the original shaft but the calculations should still be reran.
Plugging in the numbers a shaft of 1.25 inches should still work.
```

Lewis form factors - 730

```
Y_1 = 0.318; % N = 30, used chart 14-2 on page 730
Y_2 = 0.355; % N = 60,
Y_3 = 0.318; % N = 30,
Y_4 = 0.355; % N = 60,
```

K_v for machined gears - 731

```
v_1 = (diameter_1/12)*pi*rpm_in;
K_v_1 = (1200+v_1)/1200;

v_2 = (diameter_2/12)*pi*rpm_2;
K_v_2 = (1200+v_2)/1200;

v_3 = (diameter_3/12)*pi*rpm_3;
K_v_3 = (1200+v_3)/1200;

v_4 = (diameter_4/12)*pi*rpm_out;
K_v_4 = (1200+v_4)/1200;
```

Bending stress in tooth

from figure 14-6, page 745

```
J_1 = 0.385;
J_2 = 0.425;
J_3 = 0.385;
J_4 = 0.425;
% from page 752
c_mc = 1; %uncrowned
c_pf_1 = 0.025;
c_pf_2 = 0.025;
c_pm = 1.1;
c_ma = 0.127 + 0.0158*F;
c_e = 1;
k_m_1 = 1+c_mc*(c_pf_1*c_pm + c_ma*c_e);
k_m_2 = 1+c_mc*(c_pf_2*c_pm + c_ma*c_e);
k_b = 1;
k_o = 1.25;
k_s = 1;
sigma_1 = K_v_1*w_t_1*k_s*k_o*((pitch/F)*k_m_1*k_b/J_1);
sigma_2 = K_v_2*w_t_2*k_s*k_o*((pitch/F)*k_m_2*k_b/J_2);
sigma_3 = K_v_3*w_t_3*k_s*k_o*(pitch*k_m_1*k_b/(J_3*F));
sigma_4 = K_v_4*w_t_4*k_s*k_o*(pitch*k_m_2*k_b/(J_4*F));
% compare these to s_t, yeild in tention
```

Calculating safety factor, must be more than 1.5

```
load_cycles = rpm_out*life_minutes;
y_n = .9;
k_t = 1;
k_r = 1.25;
safety_factor_theoretical = (s_t_steel * y_n/(k_t*k_r))/sigma_4 ;
% if this is greater than 1.5 we are good.
if (safety_factor_theoretical > 1.5)
    fprintf("Passes bending \n")
else
    fprintf("Fails bending \n")
end
```

```
Passes bending
```

Finding minimum gear face width

```
sigma_theoretical = (s_t_steel*y_n/(k_t*k_r))/safety_factor;
f_min_pinion = w_t_3*k_o*K_v_4*k_s*(pitch/sigma_theoretical)*((k_m_1*k_b)/J_3);
f_min_gear = w_t_4*k_o*K_v_4*k_s*(pitch/sigma_theoretical)*((k_m_2*k_b)/J_4);
fprintf("Question 6: \n")
fprintf("Bending Stress: %f \n",sigma_4)
fprintf("Material Properties: \n")
fprintf("sigma_theoretical: %f \n",sigma_theoretical)
fprintf("S_c steel: %f \n",s_t_steel)
fprintf("Smallest face for gear 3 = %f \n",f_min_pinion)
fprintf("Smallest face for gear 4 = %f \n",f_min_gear)
```

```
Question 6:
Bending Stress: 7253.466838
Material Properties:
sigma_theoretical: 12000.000000
S_c steel: 25000.000000
Smallest face for gear 3 = 0.667256
Smallest face for gear 4 = 0.604456
```

Finding Sigma c

```
c_f = 1;
I = (cosd(phi)*sind(phi)/2)*(ratio_per_step)/(ratio_per_step+1);
%cp find on page 736 and 749
c_p = ((pi*(((1-.3^2)/(28*10^6))+((1-.3^2)/(28*10^6)))))^(-1/2);
sigma_c_1 = c_p*(w_t_1*k_o*K_v_1*k_s*k_m_1*c_f/(diameter_1*F*I))^(1/2);
sigma_c_2 = c_p*(w_t_1*k_o*K_v_1*k_s*k_m_1*c_f/(diameter_2*F*I))^(1/2);
sigma_c_3 = c_p*(w_t_3*k_o*K_v_3*k_s*k_m_1*c_f/(diameter_3*F*I))^(1/2);
sigma_c_4 = c_p*(w_t_4*k_o*K_v_4*k_s*k_m_2*c_f/(diameter_4*F*I))^(1/2);

fprintf("Contact Stress: %f \n",sigma_c_4)
```

```
Contact Stress: 78915.997167
```

Finding wear factor of safety

```
z_n = 0.9; % page 755
c_h = 1; %page 753, same material, same hardness
s_h = (s_c_steel*z_n*c_h/(k_t*k_r))/(sigma_c_3); % use 3 because it is biger
% if greater than 1.5 we are good
if (s_h > 1.5)
    fprintf("Passes wear \n")
else
    fprintf("Fails wear \n")
end
```

```
Fails wear
```

Finding minimum gear face width wear

```
sigma_c_theoretical = s_c_steel*z_n*c_h/(k_t*k_r)/sqrt(safety_factor);
f_pinion_theoretical = c_p^2*(w_t_3*k_o*K_v_3*k_s*k_m_1*c_f/(diameter_3*sigma_c_theoretical^2
*I));
f_gear_theoretical = c_p^2*(w_t_4*k_o*K_v_4*k_s*k_m_2*c_f/(diameter_4*sigma_c_theoretical^2*I
));
fprintf("Smallest face for gear 3 = %f \n",f_pinion_theoretical)
fprintf("Smallest face for gear 4 = %f \n",f_gear_theoretical)
```

```
Smallest face for gear 3 = 1.812793
Smallest face for gear 4 = 0.906396
```

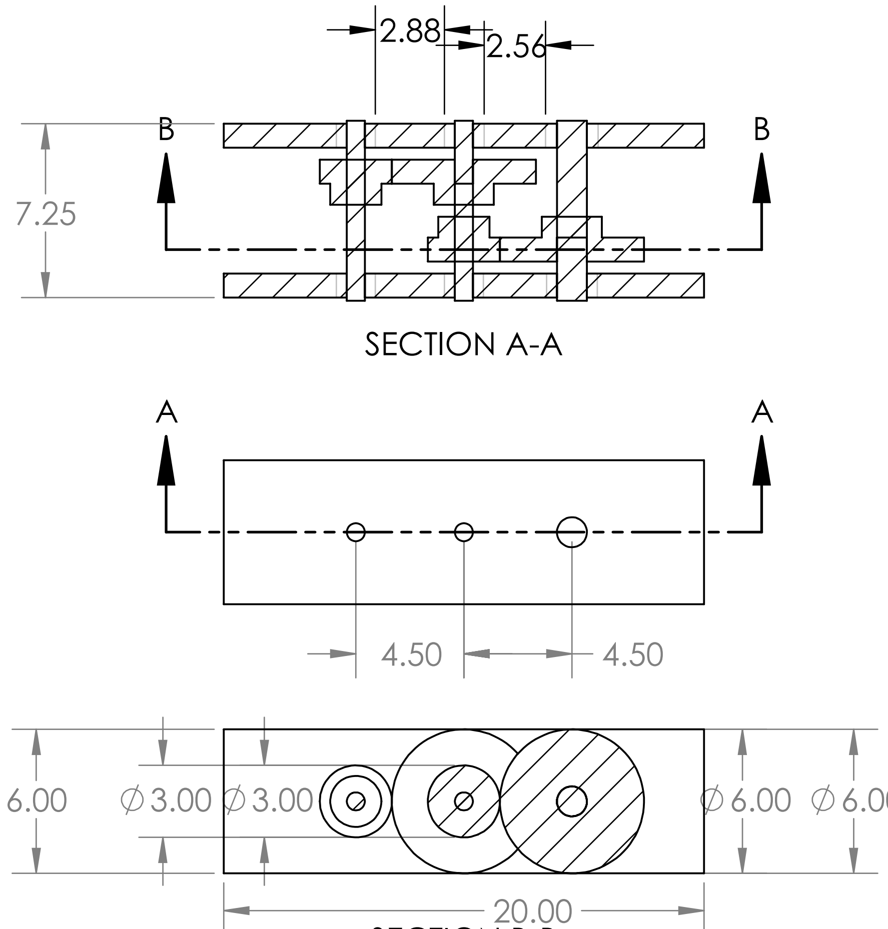
Estimating Horse power rating page 732, 14-2

Gears

Helpful example at 760, 14-4 and till 14-8 14-19 goes over how to design a gear set

```
fprintf("Question 7: \n")
fprintf("Pinion number %s \n",gear1.name)
fprintf("Gear number %s \n",gear2.name)
fprintf("Question 8: \n")
fprintf("The gears would need to be hardened to a brinell hardness of about 400 to work for m
y calculations.\n")
```

```
Question 7:
Pinion number 6867K79
Gear number 6325K9
Question 8:
The gears would need to be hardened to a brinell hardness of about 400 to work for my calcula
tions.
```



Feathered keys on all gears
Retaining rings on all shafts between end and bearing

	NAME	DATE
DRAWN	MJK	2019
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
APPLICATION	

TITLE:

Gear Drive Train

SIZE A | DWG. NO. Assem2 | REV A

SCALE: 1:8 | WEIGHT: | SHEET 1 OF 1